INTRODUCTION

TO

OIL AND GAS

EXPLORATION AND DEVELOPMENT

IN WASHINGTON

The first known oil well in the state was drilled around the turn of the century near Machias or Stanwood Station, Snohomish County. Since then approximately 435 oil and gas exploratory wells and 76 gas storage wells have been drilled in the state. Major companies drilled 110 of the exploratory wells. Thirteen wells have been drilled on state-owned land.

Less than one-fourth of the wells were drilled in Eastern Washington indicating the major interest has been in Western Washington. Extensive basalt flows and technological problems have prevented a thorough evaluation of the oil and gas possibilities in Eastern Washington.

AREAS OF DRILLING ACTIVITY

The following areas have received the most extensive attention due to the presence of oil and gas seeps nearby, accidental discovery of gas in a water well or as a result of geological or geophysical information.

Columbia Basin

A small gas field ("Rattlesnake Hills Field") was discovered in 1913 when a company was drilling for water near Grandview in Benton County. This field produced nearly 1.3 billion cubic feet of gas from 1929 to 1941. At one time the field had 16 wells which produced from depths of 700 to 1,200 feet. During 1980 to 1984 three exploratory wells were drilled in Kittitas County; three other wells were drilled in the Columbia Basin, two in Grant County and one in Benton County.

Willapa Hills, Grays Harbor County

Drilling was initiated in 1901 and continued sporadically through 1977. Many wells encountered oil and gas shows. In 1957 a producing well was drilled. This well ("Medina No. 1") produced 12,000 barrels of oil before being plugged and abandoned. This is the only well to date in the state to produce oil.

Olympic Mountains, Clallam and Jefferson Counties

Oil seeps were first reported in Washington about 1881 along the sea cliffs on the west side of the Olympic Peninsula. Outcrops of shale having a kerosene odor were also noticed along the beach on the western side of the peninsula. Natural gas seeps associated with mud cones and mounds have been reported in this same general area.

The area of interest is located in Clallam and Jefferson Counties on the west side of the Olympic Peninsula in the general vicinity of the town of Forks. Since the first well was started at the turn of the century, 33 exploratory wells and five core holes have been drilled in this area. The majority of these exploratory wells had shows of oil or gas. Seeps of both oil and gas have been known in this area. Minor drilling has taken place in Clallam County along the Strait of Juan de Fuca. Modest shows of oil and gas have been encountered in these tests.

Whatcom County

About five miles northwest of Bellingham in western Whatcom County gas in sufficient quantity for domestic use was obtained from glacial sand lenses at depths of less than 500 feet. More than 95 wells have been drilled; most were shallow.

Puget Lowland

Although this area covers approximately 6,000 square miles it is being considered as a unit because of the similarity in rock strata, oil and gas environment and the broad drilling program. Approximately 95 wells have been drilled with shows of oil or gas in over half.

Aquatic Lands

Exploration interest in lands on the continental shelf off Washington's coast has remained fairly steady for a number of years. To date, six wells have been drilled in this area but no production has occurred.

Aquatic lands in every county abutting the ocean have been leased for oil and gas exploration in the past; 100,000 acres were leased in 1978. Two wells have been drilled on department aquatic lands; neither well was productive.

Interest has also been expressed in leasing aquatic lands under the Strait of Georgia, Strait of Juan de Fuca and the Columbia River.

POTENTIAL AREAS OF OIL AND GAS INTEREST IN THE STATE OF WASHINGTON

Washington State is a substantial user of petroleum products but has not yet become a contributor to the supply, although over 435 wells have been drilled to date in search for petroleum with little or no commercial success. Only about one-fourth of the holes were located using modern technology.

Several sizeable areas within Washington State and on the adjacent continental shelf possess all of the major geologic characteristics that are required for the accumulation of commercial quantities of petroleum; for example, source rocks, reservoir rocks, proper structures and stratigraphy.

Considering the large areas involved, it can be calculated that less than one test well for every 200 square miles of favorable area has been drilled. Because of the complex structures and poor exposures of rock in Washington, exploratory drilling must be spaced much closer together before the favorable areas have been adequately tested.

AREAS OF INTEREST

The order in which the following specific areas of interest are discussed does not imply a rating of the areas as to potential for exploration or interest.

Columbia Basin

The Columbia Basin occupies roughly the southeastern quarter of the state. It lies south of the Okanogan highlands and east of the Cascade Mountains and extends southward into Oregon and eastward into Idaho to the foothills of the Rocky Mountains. Surface geology, water wells and some oil and gas exploration wells indicate the basin is underlain mainly by basaltic lava flows. Along the northern and eastern boundaries of the basin the basalt flows are underlain by igneous and metamorphic rocks generally of little interest to the petroleum industry. However, along the western margin of the basin, the basalts rest upon continental (nonmarine) sedimentary rocks and older lavas. These sediments contain coal beds in the Roslyn-Cle Elum area and extend eastward under the basalt flows for an unknown distance. Marine strata in north central Oregon are known to occur and may extend northward into Washington. In the western part of the Columbia Basin, the subsurface rocks may possibly hold hydrocarbon potential if the structural conditions prove favorable.

In spite of the extensive amount of basalt which occurs in the Columbia Basin, oil and gas shows have been encountered. The Rattlesnake Hills Field mentioned earlier was discovered near Grandview in Benton County. Wells drilled in other areas of the basin have produced shows of gas. Wells drilled in 1981-82 in Kittitas County reportedly contained substantial although subcommercial shows of gas. Oil and gas leasing and exploration activities continue in the Columbia Basin area.

Willapa Hills

The Willapa Hills and adjacent areas of southwestern Washington include all the territory south of the Olympic Mountains and west of the Puget Lowland, an area of approximately 3,500 square miles. Here strata have potential source beds for petroleum generation and potential reservoir rocks for petroleum accumulation. These rocks have been tested locally and excellent indications of petroleum have been found. Subcommercial production has been obtained in four wells. Numerous wells have been drilled on favorable geologic structures located in the area. This area continues to attract the interest of the oil and gas industry and will probably continue to receive exploration interest.

Olympic Peninsula

The Olympic Peninsula has continued to interest the industry over the years, particularly along the north flank of Clallam County, along the Strait of Juan de Fuca and in the western part of the Peninsula near the community of Forks and the mouth of the Hoh River. On the north side of the peninsula a section of strata of more than 15,000 feet has yielded petroleum shows in some wells. Additional exploration activities can be anticipated for this locality. The central core of the Olympic Mountains consists of rocks that presumably have little petroleum potential and are classified as unfavorable.

Whatcom County

In western Whatcom County, gas in sufficient quantity for domestic use has been obtained from glacial sand lenses at depths of less than 500 feet. To date, more than 90 wells have been drilled. Most of the wells reported gas shows. A few reported oil shows. The industry continues to show interest in this area and more exploratory activity can be expected in the future.

Puget Lowland

The Puget Lowland, including much of the area between the Olympic Mountains and the Cascade Range, has for some time been regarded as potentially favorable for oil and gas production. Unfortunately, much of the lowland is covered with glacial deposits, making exploration difficult. However, new techniques being developed will help solve this difficulty. Much exploration is required in this potentially favorable area before it will have been adequately tested.

Surface geologic mapping has delineated several structures and faults in the Puget Lowland and geophysical investigations have outlined a few deep structures in the basin. Considerable drilling on the surface structures has been done in central Lewis and western King Counties. Oil traces or shows have been reported in 14 tests and gas shows reported in 16 others.

Aquatic Lands

Aquatic lands on the continental shelf include both state (from the coastline seaward for three nautical miles) and federal (beyond the three-nautical-mile line) land. Sedimentation basins of the continental margins of the Pacific Northwest are considered by some to hold great potential for oil and gas production.

Continuous seismic profiling surveys indicate that structural and stratigraphic conditions in this large area are favorable. However, only a minor amount of drilling has occurred and many favorable geologic structures on aquatic lands remain unexplored.

SUMMARY

Exploratory test wells in the state of Washington have disclosed evidence of petroleum and natural gas in more than 100 wells but only minor production has been obtained. The state contains areas that possess the three geologic features that are required for the accumulation of commercial quantities of petroleum and natural gas. These are:

1. An adequate source of petroleum-generating material in the form of abundant marine animal or plant life.

2. The presence of reservoir rocks in which important amounts of oil and gas can accumulate and from which they can be made to flow to wells for production at satisfactory rates.

3. Suitable structural or stratigraphic conditions that provide a means of localizing and entrapping the oil or gas in the reservoir rocks.

Whether these three factors will be found in a combination that would provide major commercial production of petroleum or natural gas has yet to be determined although surface and subsurface indications are favorable in many areas.

PHASES OF ACTIVITY

Major phases of activity in the oil and gas industry as they relate to this program are: Exploration, Development and Production, and Reclamation.

1. **Exploration** -- This phase includes all activities conducted by an operator or company from the decision to investigate an area through preliminary evaluation. They are:

   - Surface geologic mapping, geophysical mapping including explosive seismic surveys;
   - Land and lease evaluation;
   - Stratigraphic test hole drilling;
   - Exploratory drilling; and
   - Reclamation -- plugging and abandonment of drill holes, removal of waste materials, closing of access roads and site restoration.

2. **Development and Production** -- This phase is one of intense activity if oil and gas are found in commercial quantities. It requires:

   - Drill site development;
   - Construction of flow and gathering lines, storage, processing and treatment facilities;
   - Production;
   - Maintenance of facilities;
   - Waste disposal - at approved sites, or in the case of fluids into approved strata containing waters of equal or lesser quality (in conformance with the Underground Injection Control Program of the Federal Safe Drinking Water Act); and
   - Reclamation - site cleanup, removing unnecessary structures and plugging wells as they become unnecessary to development and production.

3. **Reclamation** -- This is the final abandonment phase and includes:

   - Plugging and abandoning of production and injection wells;
   - Removing all surface facilities;
   - Restoring the site; and
   - Closing and reclaiming haul and access roads.

EXPLORATION

Geophysical Mapping, Exploration or Surveys

The exploration phase uses a wide range of scientific research methods to locate possible oil and gas bearing strata. Geophysical surveys normally are conducted before an oil and gas lease is obtained, but are not necessarily requisite to obtaining a lease. The operator or company decides where geologic and geophysical mapping is to be conducted.

Geophysical surveys may be conducted after a lease is obtained or after exploratory drilling to further delineate the structures and strata at depth. The procedures are described here to provide an overview of administrative activities relating to such surveys.

Geophysical surveys such as gravity and magnetic can be conducted from existing roads and trails or from air borne equipment. Seismic surveys, one of the more frequently used methods of geophysical investigation, occasionally require the clearing of new access trails or roads and the movement of heavy equipment.

In seismic surveys, a sound wave is sent into the subsurface and the time required for the wave to travel to and return from a subsurface horizon is recorded. (See Figure 2.) Interpretive maps can be drawn from an analysis of the differences in time it takes the wave to be reflected back to the surface from the various rock formations. Explosive, vibrator or thumper methods are used to produce the sound wave. In the explosive method, generally shot holes are drilled to a depth of between 50 and 200 feet deep with 1 to 12 holes per mile and loaded with 5 to 50 pounds of explosive and detonated. The same hole is occasionally loaded and shot several times to find the depth and explosive charge returning the best reflection or refraction signal. The vibrator and thumper methods pound or vibrate the earth to create a sound wave. Thumper surveys are not commonly used (personal communication, Larry Bowles, International Assoc. of Geophysical Contractors).

The sensors and energy sources are located along straight lines laid out on a 1- to 2-mile grid. The energy sources are normally truck mounted and constitute heavy equipment. Existing road systems are used where available. Lines may be cleared of vegetation and loose rocks to improve access for the trucks. Each mile of line cleared to a width of 8¼ feet uses 1 acre of land.

Stratigraphic Test Holes

Stratigraphic test holes are drilled to depths of less than 2,000 feet to locate geologic indicators. The holes are usually drilled with truck-mounted equipment and disturb a relatively small area. Stratigraphic holes are cased in areas of shallow, high pressure zones or where otherwise required by the Oil and Gas Supervisor. The roads and trails constructed for access are temporary and involve minimal construction. The drill site occupies approximately 900 square feet and is sometimes placed in the center of an existing trail or road.

Exploratory Drilling

Exploration begins with company geologists reviewing geological and technical data available from the region. Seismic shot holes, stratigraphic test holes or exploratory wells (wildcat) are drilled on a very small percentage of the areas involved in preliminary investigations. Exploratory drilling does not begin until a lease has been acquired by the operator. Washington State, through the Oil and Gas Conservation Committee, regulates exploratory drilling.

Wildcat Wells

Wildcat wells are deeper tests (usually over 2,000 feet) and require larger drilling rigs with support facilities. They may disturb a larger surface area than stratigraphic tests. (See Table 2.) Required facilities include roads, drill pads, mud pits and, in rare instances, camps.

After a drilling site has been selected, a heavy-duty road is constructed to move the drilling rig and other equipment to the location if existing roads will not suffice or roads do not exist.

Figure 2 Seismographic Testing

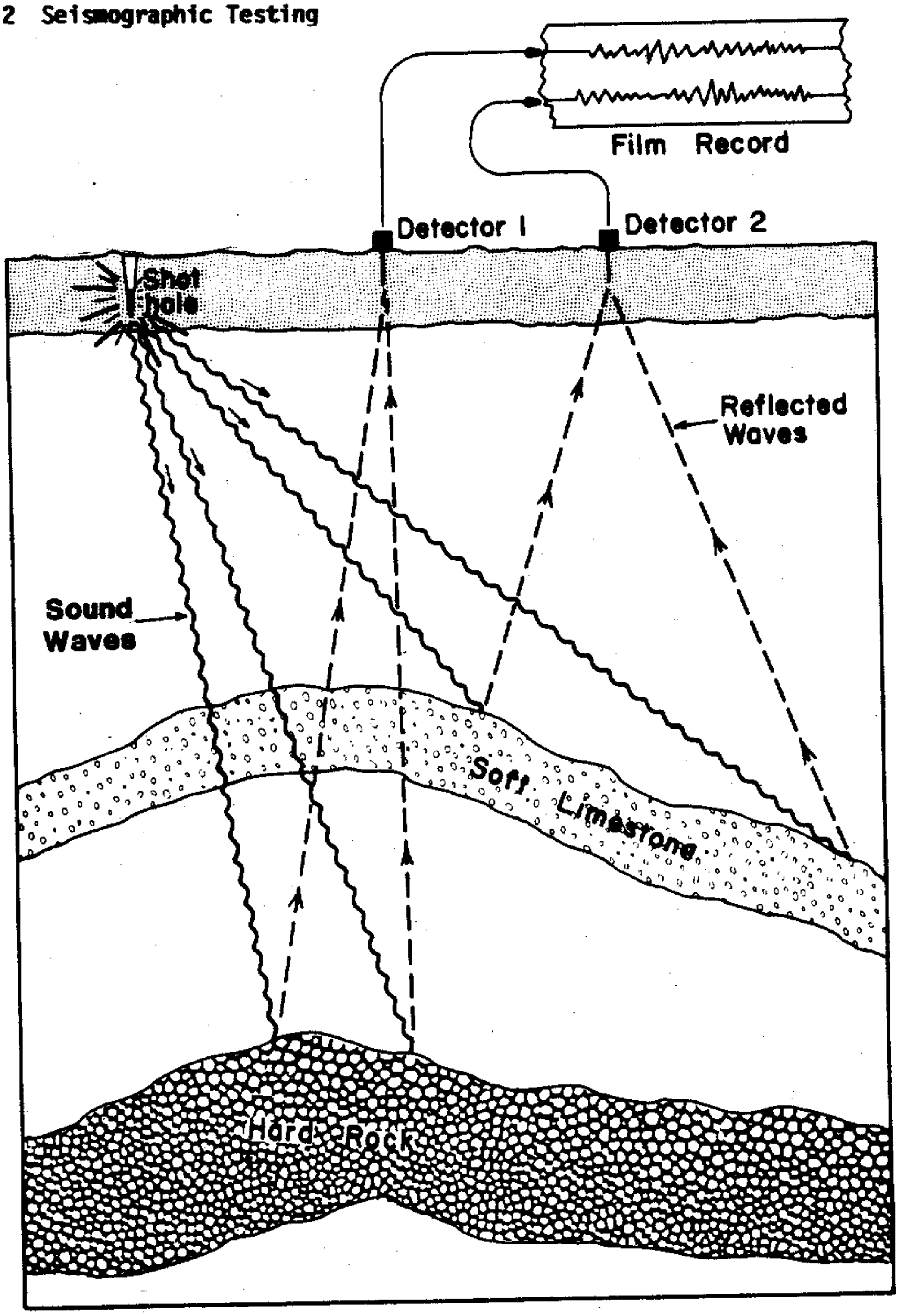


Table 2 Estimated Acreage Requirements Within a Lease Section for Gas or Oil Development.

	Well Spacing	
	1 Well Per Section*	4 Wells Per Section†
Drill Pad	4 acres‡	16 acres‡
Roads (18 ft. wide)	2.2 acres (1 mi. required)§	4.4 acres (2 mi. required)**
Pipelines (corridor 25-50 ft. wide)	3-6 acres (1 mi. required #	6-13 acres (2 mi. required)**
Central collection, separation, and storage facilities	Unable to determine at this time.	

* Probable gas development spacing. Minimum spacing per RCW 78.52.210

† Probable oil development spacing. Minimum spacing per RCW 78.52.210

‡ Half of this acreage would be rehabilitated upon completion of drilling activity. The remaining acreage would be rehabilitated upon abandonment.

§ Could vary from approximately 1.1 - 3.3 acres (.5 - 1.5 miles of road) depending on position of well in section and topography.

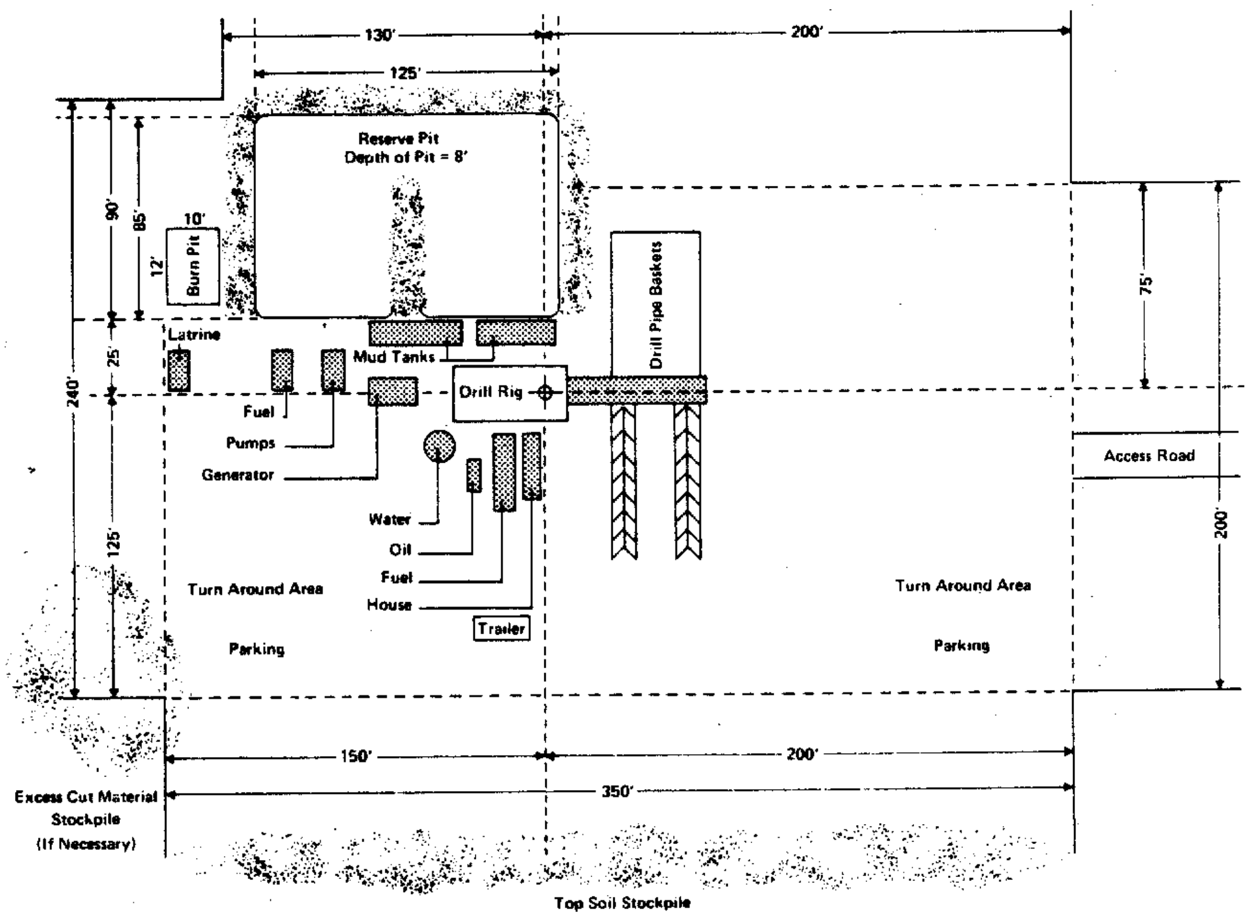
\# Could vary from approximately 1.5-9.1 acres (.5-1.5 miles of pipeline) depending on position of well in section, topography and width of pipeline corridor.

** Minimum required.

The well site may occupy one to four acres and is cleared of all vegetation and graded nearly flat. Depending on the soil in the area, the well site or drill pad and roads may or may not be graveled. A concrete cellar or substructure is constructed to serve as a base for the blowout prevention equipment and as a support for the rig. In addition to the drill rig, mud pumps, a mud pit, generators, pipe racks, a tool house and personnel office trailers are located on the drill pad (Figure 3 and 4). Other facilities such as storage tanks for water and fuel may be located on or near the drill pad.

A water supply is required for mixing drilling mud, cleaning equipment, cooling engines and other uses. The water may be trucked in to the site or a pipeline may be laid to a pump installed in a stream or to a water well.

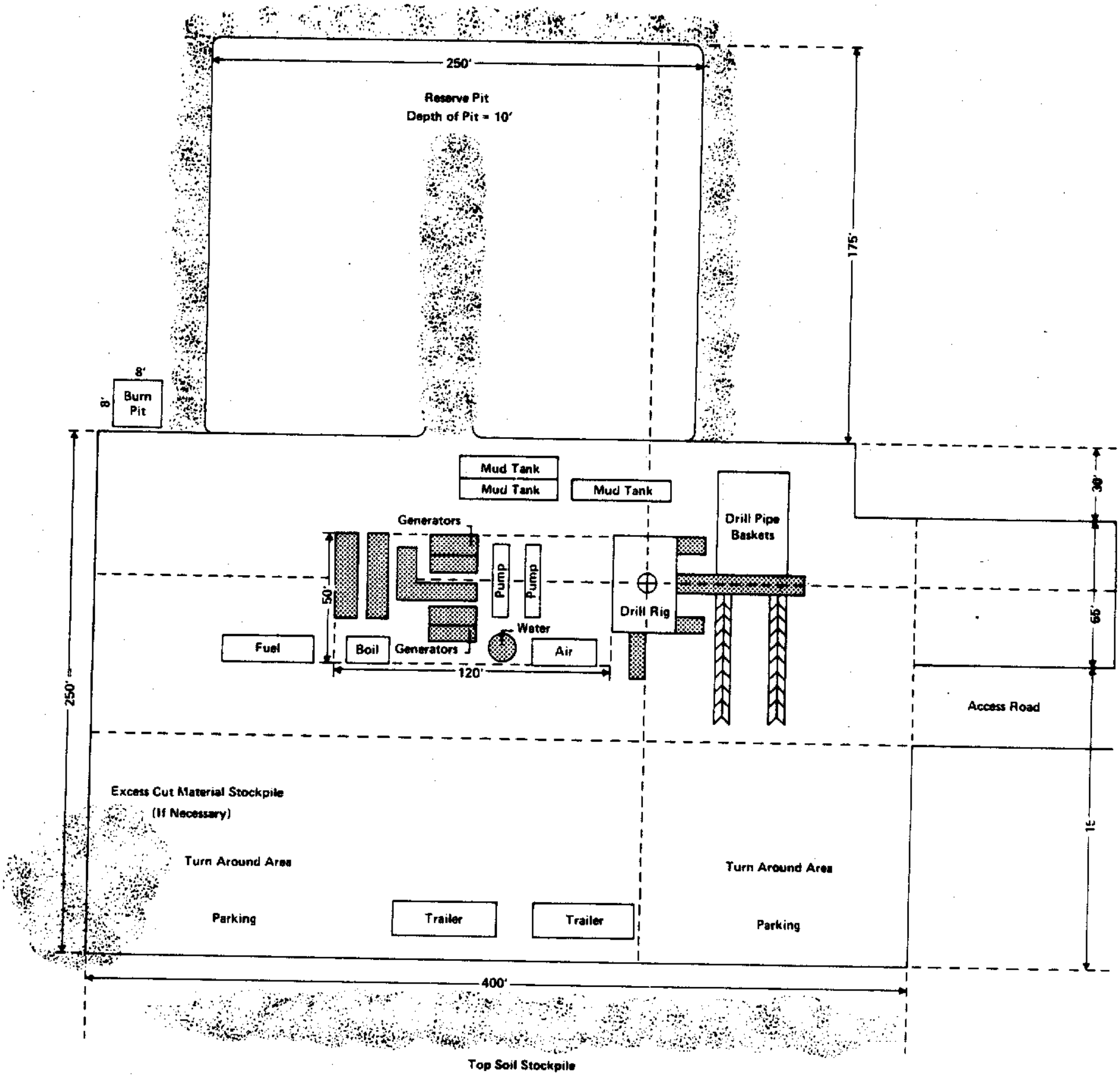
Figure 3 Location Layout for a Well 6,000 to 9,000 Feet Deep



Source: U.S. Dept. of Interior, 1980a.

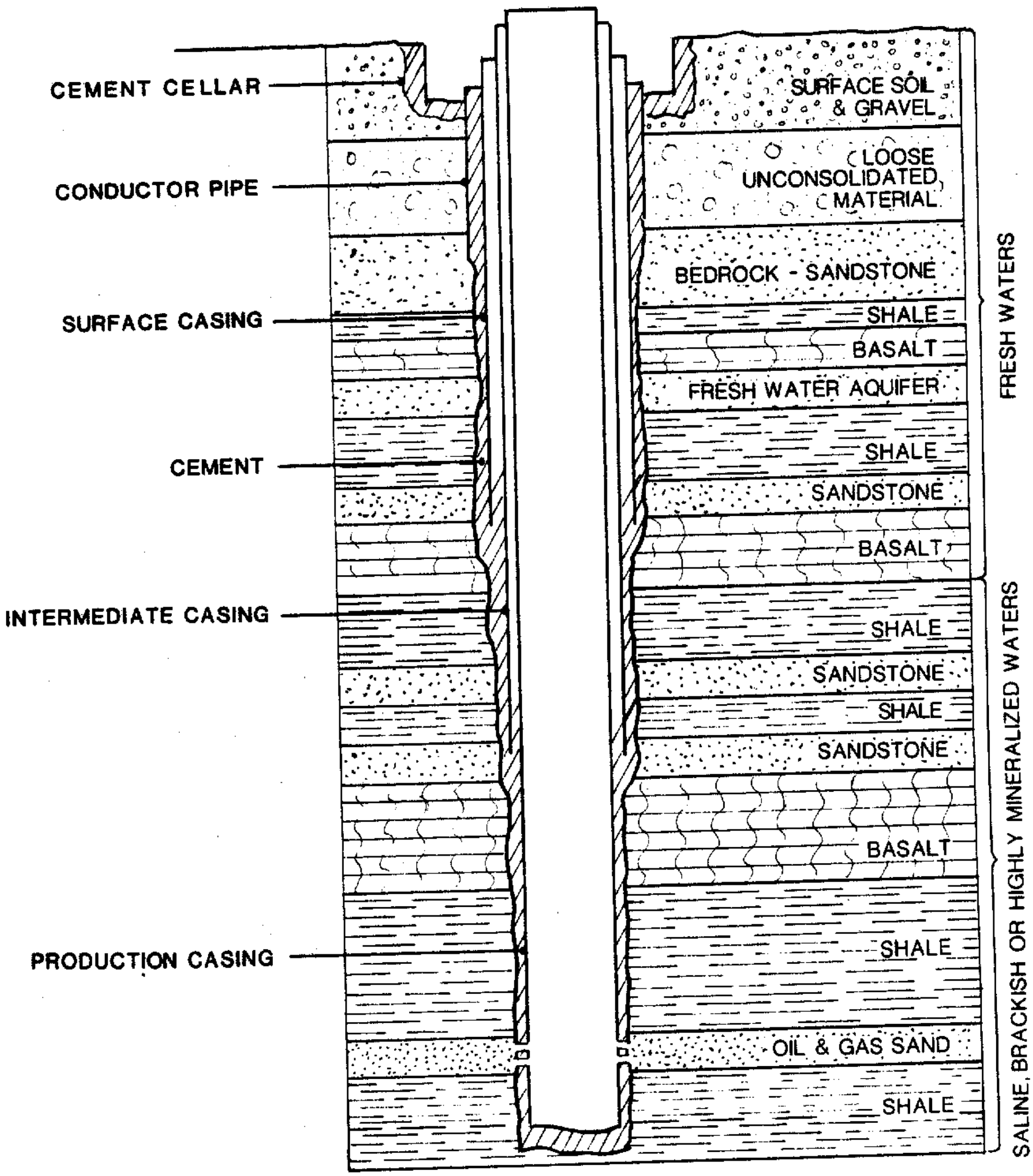
Oil and gas field drilling practice requires setting conductor pipe to a depth of 15 or more feet to keep surface materials from sloughing into the well. Surface casing is set to a depth deemed necessary by the Oil and Gas Supervisor to protect any fresh water zones and to keep the well from blowing out in the event a high pressure zone is encountered. As the well deepens the drilling crew adds additional joints of drill pipe to the top of the drill string. Additional strings of intermediate casing may be necessary to protect the drill hole from sloughing or blowout. (Figure 5.)

Figure 4 Location Layout for a Well 9,000 to 15,000 Feet Deep



Source: U.S. Dept. of Interior, 1980a.

Figure 5 Oil/Gas Well Casing



The physical and chemical characteristics of the drilling mud are maintained to cool the drill bit, reduce drag of the drill pipe on the sides of the well bore, seal off any porous formations, contain formation fluids to prevent a blowout or loss of drilling fluid and bring the drill cuttings to the surface for disposal. Various additives are used to maintain the drill mud at the proper viscosity and weight.

Some of the additives may be caustic, toxic or acidic. Others are simply inert weight and fluid additives. Requirements may be placed on the transport of additives to and from a drilling site. The drilling permit may contain clauses to preclude the use of toxic or acidic additives if site conditions warrant it. When applying for a permit to the Oil and Gas Conservation Committee the operator must specify what additives will be used. Drilling mud materials are listed in Appendix A.

Storage tanks are required to hold oil produced from an exploratory well. A separator may be required to separate the oil and gas. If water is produced with the oil, a treater may be needed. When water is produced along with oil and/or gas it may (subject to approval) be disposed of by injection into the producing formation, by injection into another formation containing water equal to or of lesser quality than the produced water or (depending on quality) be allowed to evaporate from a surface impoundment or disposed of in streams. Gas separated from the oil may be burned off (flared) as waste during the initial stage of oil field development. If gas is discovered, only that amount of gas necessary to determine the well's capacity is permitted to be flared. The well is shut-in until the gas line is constructed.

Well completion requires installation of steel casing inside the surface casing projecting down to or through the pay (production) zone. The casing is selectively cemented to provide adequate anchoring and stability and to protect specific zones. The drilling rig and most of the support equipment are usually removed from the well site after the casing is cemented. The completion of a wildcat well as a commercial producer usually marks the beginning of the development phase.

DEVELOPMENT AND PRODUCTION

A development unit (well spacing or pattern) must be established under the provisions of Chapter 78.52 RCW and Chapter 344-12 WAC before development drilling begins. The development unit is determined by the Oil and Gas Supervisor after public hearings. RCW 78.52.210 sets a maximum of 160 acres for an oil reservoir and 640 acres for a gas reservoir.

Current Washington law (RCW 78.52.210) sets a maximum spacing of 160 acres per oil well. Minimum spacing probably will not be less than one well per 40 acres, with each well separated by one-fourth mile. With 40-acre spacing (16 wells per square mile) approximately four miles of access roads and four to six miles of flow lines connecting wells and tank battery would be required.

Surface uses for a gas field would be significantly less than in an oil field. Gas wells can be spaced from one per 160 acres down to one well per 640 acres. A 160-acre spacing would require four wells per section and two miles of access roads and pipelines. Separation and storage facilities are not required for gas production unless the production is rich in liquids or condensate. Gas may be sold without separation at the production site.

The procedures used in drilling development wells are the same as those used for a wildcat well. Additional surface facilities required for development drilling may include access roads, well sites, flow lines and storage tank batteries; and facilities to separate oil, gas and water. Remote locations may require camps and heliports, but this is unlikely in Washington.

Well facilities in oil fields vary depending upon whether the well is a flowing or pumping well. Pressures in some oil reservoirs are great enough to force oil to the surface. This results in a flowing well. Most oil wells in the United States will require the use of some means of artificial lift to bring the oil to the surface. Pumping and a technique known as "gas lift" are the two methods of artificial lift used at present. Flowing wells and wells with gas lift facilities require a minimum of equipment at the surface and produce little or no sound. All pump systems require more surface equipment.

The surface equipment at the head of a flowing well consists of the well head equipment or "Christmas tree" (a series of valves and pipe connections connecting the well head to the flow lines). The area around the well head and pipe connections is fenced. The area required ranges from 15' by 15' to 50' by 50'.

Over 90 percent of the oil wells in the United States in 1971 were on artificial lift and most artificial lift wells use sucker rod pumps. Other pumps used on oil wells are hydraulic and centrifugal pumps. All of the pump systems require some surface equipment and fuel or electric power lines. All generate some noise, ranging from almost none for electric motors to high noise levels for single cylinder gas engines.

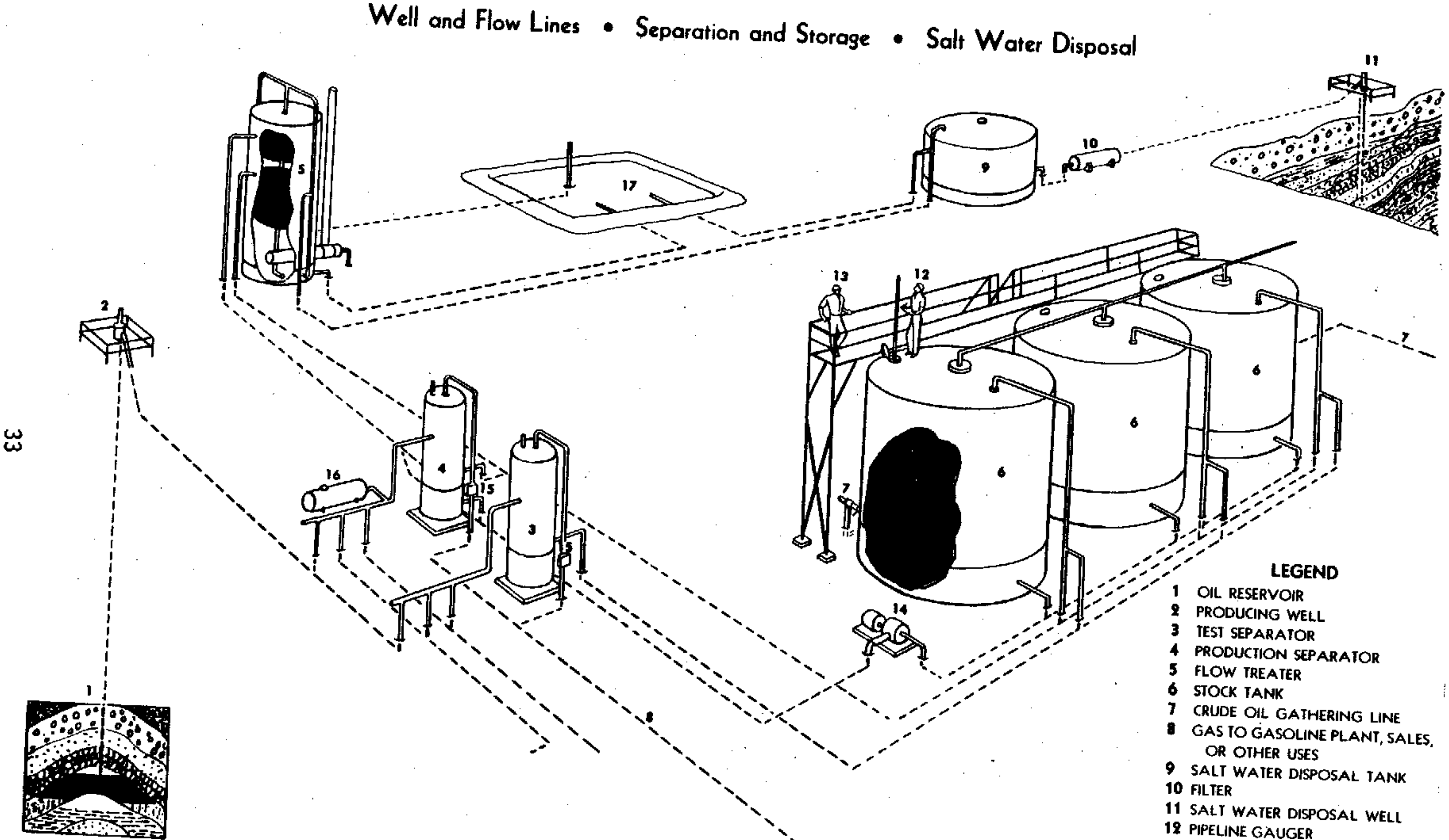
Gas lift is used in some oil fields where low cost, high pressure natural gas is available and where pressure in the petroleum reservoir is sufficient to force the petroleum part of the way up the well. The addition of gas lowers the specific gravity of the petroleum so that it flows to the surface. The system is quiet and uses little ground.

Most gas wells produce by normal flow and do not require pumping. Surface use at a flowing gas well usually is limited to a 20' by 20' fenced area. If water enters a gas well and chokes off the gas flow, a pump may be installed to pump off the column of water.

Oil and gas are transferred from the wells to central collection points and flow lines. The flow lines usually are three- or four-inch diameter steel pipes. They may be buried, installed on the surface or elevated. Flow lines transfer crude oil from the wells to a central collection point, or storage tank battery (two or more), before the oil is transported from the lease (Figure 6). Natural gas is often sold at the well head and transported directly off the site via pipeline. If processing is required to remove liquid hydrocarbons or water, the gas may be transferred to a central collection point prior to sale.

There are various separating, treating and storage facilities involved in oil and gas production. If the fluids produced at the well contain gas and water, the oil, gas and water are separated before the oil is stored in the tanks. The tanks are usually located on or near the lease. Small leases may contain only one tank battery; large leases may contain several. Each battery contains separating, treating and storing facilities.

Figure 6 Flowing Oil Production



LEGEND

1 OIL RESERVOIR
2 PRODUCING WELL
3 TEST SEPARATOR
4 PRODUCTION SEPARATOR
5 FLOW TREATER
6 STOCK TANK
7 CRUDE OIL GATHERING LINE
8 GAS TO GASOLINE PLANT, SALES, OR OTHER USES
9 SALT WATER DISPOSAL TANK
10 FILTER
11 SALT WATER DISPOSAL WELL
12 PIPELINE GAUGER
13 LEASE PUMPER
14 CIRCULATING PUMP
15 GAS METER
16 CHEMICAL INJECTION
17 EMERGENCY SALT WATER PIT

Source: Dept. of Interior, 1963.

Although most water produced with oil and gas is brackish to highly saline, some produced water is fresh enough for beneficial surface use. Saline water is usually disposed of by subsurface injection. Evaporation pits may be used in arid regions where evaporation rates are high, such as the Columbia Basin.

When surface water is disposed of underground, it is introduced into a subsurface horizon containing water of equal or poorer quality. The disposal of any water underground must comply with the provisions of the Oil and Gas Conservation Act, Underground Injection Control regulations of the Department of Ecology and the Underground Injection Control provisions of the Federal Safe Drinking Water Act developed to protect freshwater aquifers.

Primary production of oil occurs when energy in the reservoir is sufficient to drive the oil to the well. When natural reservoir energy sources are inadequate or have become depleted, secondary production methods involving gas or liquid injection may be used to supplement the natural forces. Secondary techniques for improving oil recovery may involve one or more of the following techniques: Water flooding, miscible flooding, fire flooding, steam flooding and natural gas injection. Natural gas also is injected into some oil reservoirs during primary recovery as a pressure maintenance program.

Water flooding is the injection of water under pressure into the reservoir to drive additional oil to the producing wells. This is probably the most commonly employed form of secondary recovery. A successful water flood may increase recovery approximately 100 percent. In miscible flooding, chemical compounds, including detergents, are injected into the reservoir to break down the oil molecule or reduce viscosity. Fire flooding involves initiation of a controlled fire in the reservoir with the resulting heat and increased pressure forcing the oil to the well. Steam flooding is used to reduce the viscosity of the oil to permit it to flow more readily to the well. Some of the techniques have been used for tertiary recovery after a water flood.

In some gas condensate reservoirs, some of the components of a gas condense into liquid form near the well bore when production reduces pressure in the reservoir. The resulting reduction in pressure may cause a significant loss in recovery. To prevent this, gas is injected to maintain pressure above the lower condensation pressure.

Directional Drilling

Directional drilling is the intentional deviation of a wellbore from the vertical. Although wellbores are normally drilled vertically, it is sometimes necessary or advantageous to drill at an angle. Controlled directional drilling makes it possible to reach subsurface areas laterally remote from the point where the drill enters the earth. For example, directional drilling is used to drill from convenient and accessible locations to bottom beneath locations impossible or inaccessible for normal drilling sites, such as:

- Steep, mountainous terrain,
- Unstable land,
- Swamps, rivers, lakes and
- Residential areas.

In directional drilling the average rate of variation from the vertical is 5 degrees per 100 feet of hole drilled.

Some holes have been drilled at a rate of variation of 6 to 8 degrees per 100 feet. The maximum drift angle that can normally be maintained is 80 degrees. However, angles as high as 90 degrees have been reported. Two types of directionally drilled holes are used. In one the drift angle is increased at a uniform rate to the desired maximum deflection angle until the target depth is reached (Figure 7A). In the other the drift angle is increased at a uniform rate until the maximum deflection angle is attained, then the wellbore is brought back to vertical (Figure 7B). The capabilities of directional drilling are illustrated by a well drilled in California which had the bottom of the well displaced 9,882 feet horizontally from the surface location (Figure 8). (See page 36 for Figures 7 and 8.)

RECLAMATION

Exploration

Reclamation of stratigraphic test holes and dry wildcat well sites begins with plugging and capping the well. The drilling rig is used to plug the hole and then removed. The casing is cut off below normal cultivation depths. Drilling fluids and cuttings uncontaminated by toxic additives may be disposed of in the mud pit at the site (subject to approval from the Oil and Gas Supervisor).

Contaminated fluids and cuttings are transported to a DOE-approved disposal site. The drill pad surface, including the reserve mud pit, is restored to its original condition insofar as possible. Access roads are reclaimed as required by DNR or surface owners. The state or surface owners may retain access roads for future use.

Development and Production

Production wells and injection wells are plugged and capped after the lessee demonstrates the well's unsuitability for further profitable production. In some cases, wells are plugged as soon as they are depleted. In other cases, depleted wells are not plugged immediately, but are temporarily capped and allowed to stand idle for possible later use in secondary recovery operations.

LEASE ABANDONMENT

When an entire lease is abandoned, all surface facilities, including separators, treaters, tanks and other processing and handling equipment are removed and the surface is restored. Flow lines and injection lines installed on the surface are removed, but buried lines usually are left in place. The surface is restored to its original condition insofar as possible. Access and haul roads are restored.

Figure 7 Directional Drilling

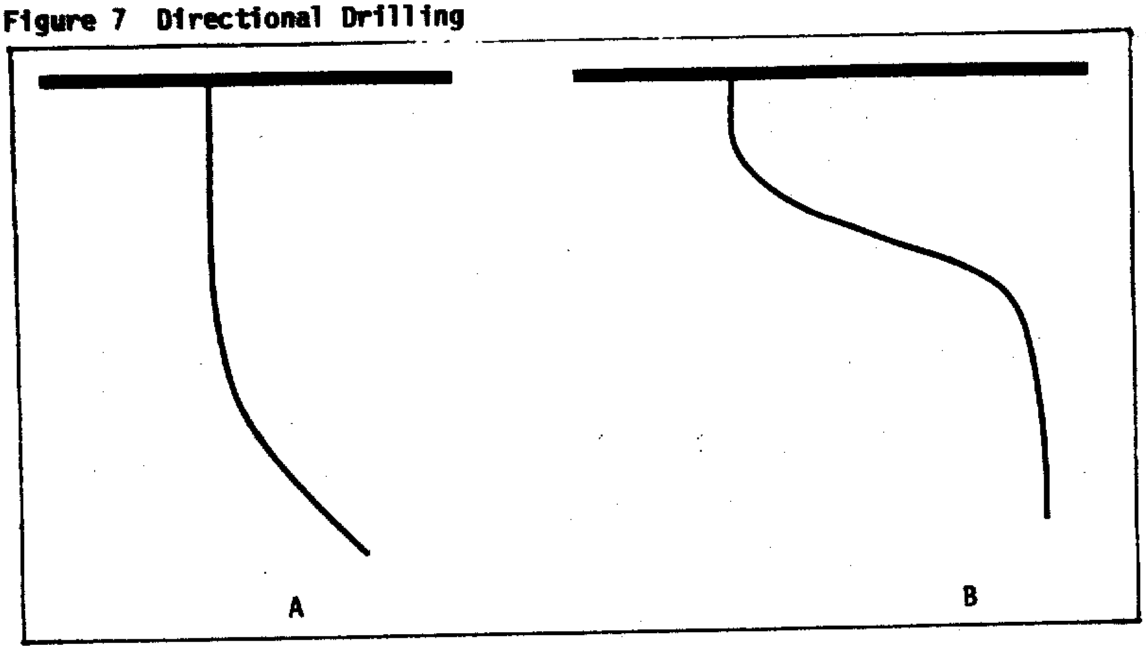


Figure 8 Example of Possible Horizontal Displacement